

Time-resolved x-ray diffraction imaging of ferroelectric domains  
in barium titanate single crystals.

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The high brilliance of the Advanced Photon Source coupled with a high-resolution CCD imaging system makes it feasible to employ full-field x-ray diffraction imaging with sufficient throughput as demanded by time-resolved investigations. We present new exciting results on an old problem: nucleation and growth kinetics of ferroelectric domains.

Understanding the mechanism of nucleation and growth of ferroelectric domains is an on-going subject of numerous theoretical and experimental investigations. The ferroelectric transition and the domain structure are intimately coupled to dielectric, ferroelectric, piezoelectric, pyroelectric, and non-linear optical properties in a wide range of materials [1]. Since 1950s, the static arrangement and growth kinetics of anti-parallel ( $180^\circ$ ) domains in barium titanate ( $\text{BaTiO}_3$ ) have been investigated using optical microscopy-based techniques in conjunction with ex-situ treatment such as chemical etching. X-ray diffraction imaging has been instrumental in measuring the static arrangement of the anti-parallel domains [2] and the strain distribution across the static domain walls [3]. However, the complexity of the nucleation behaviors requires time-resolved investigation under in-situ control of sample temperature and electric potential.

Using a brilliant APS undulator, we have imaged the growth of the anti-parallel domains in barium titanate with unprecedented contrast and acquisition rate up to 10Hz. Growth of domains under different potential conditions is shown in Fig. 1. The presentation will focus on interesting growth kinetics of anti-parallel domains and the quantitative analysis methods. The applicability of this technique to other scientific problems, as well as the ultimate capabilities and the limitations will be addressed.

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### References

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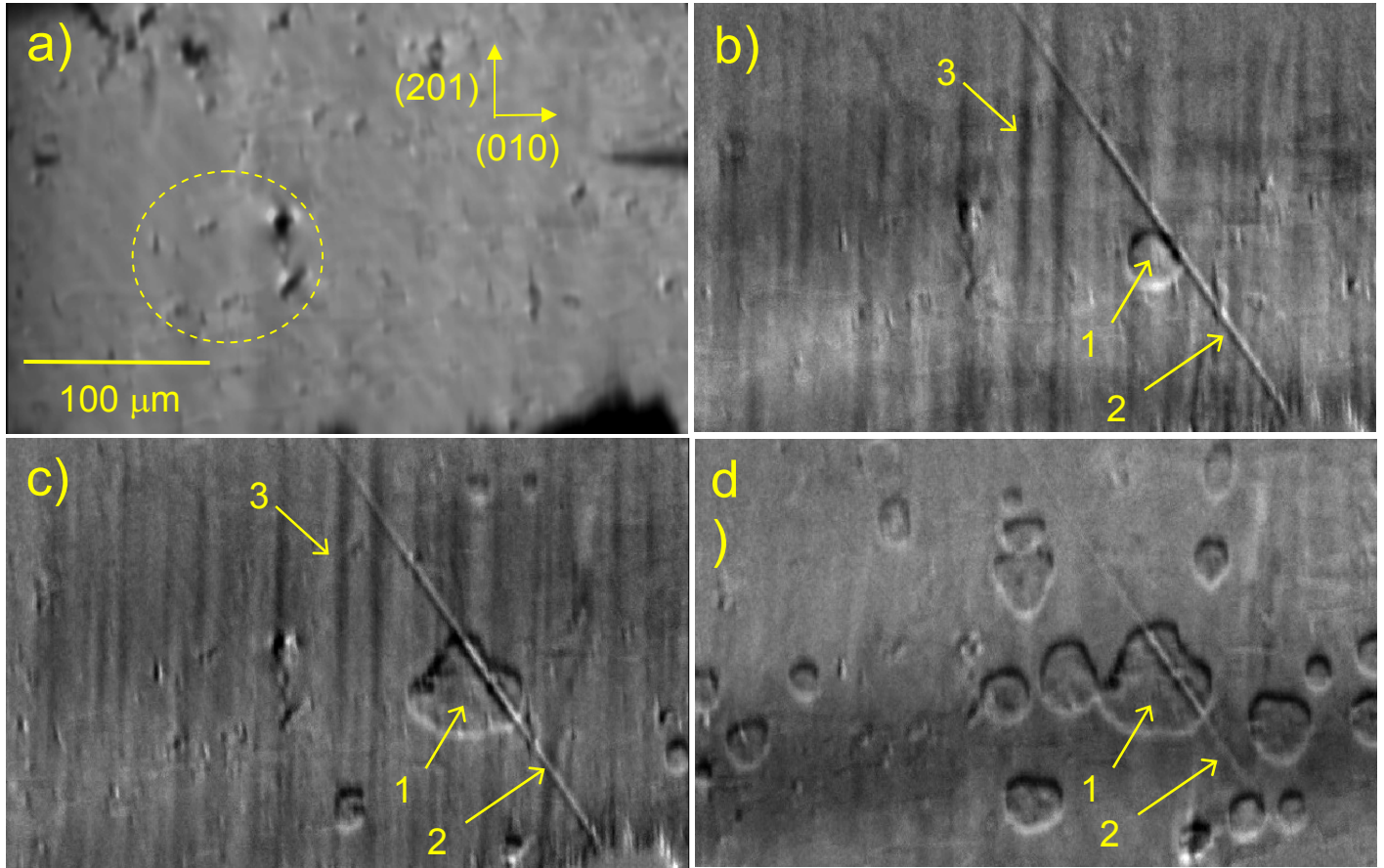


Fig. 1: X-ray diffraction images taken from a barium titanate single crystal sample. The images were taken at a (201) reflection using asymmetric Bragg geometry. A mono-domain state shown in a) was prepared by field-cooling from 130°C to 105°C. The anti-parallel domains were imaged at 0V after applying a DC potential: b) from -5 to 5V, c) from -10 to 10V, d) from -15 to 15V for 1 second. Some of the surface defects commonly visible in all four images are indicated by a dotted circle in a). The round dimple-like shapes with the potential-dependent growth rates are the anti-parallel domains with their electric polarization opposite to the rest of the crystal. Arrow 1 shows the potential dependent growth rate of one domain. The line-like feature, indicated by arrow 2, is a 90-degree domain. The vertical intensity streaks (indicated by arrow 3) visible in b) and c) are the artifacts due to beam motion during the measurement.